MASTER OF SCIENCE
IN
ASTRONAUTICAL ENGINEERING

MODAL TESTING AND ANALYSIS OF THE NPS SPACE TRUSS

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This thesis deals with modal testing and analysis of the Naval Postgraduate School (NPS) Space Truss. A finite element model (FEM) was developed for the truss using a MATLABTM program called NRLFEMI (developed at the Naval Research Laboratory). Analytical predictions of the natural frequencies for this 3.76 meter by 0.35 meter precision structure were calculated using the NRLFEMI code. These calculated natural frequencies were then compared to experimental data collected during modal testing of the truss in the NPS Dynamics and Control Laboratory. Through analysis, the predicted results of the measurements (from the FEM) were satisfactorily correlated to the experimentally obtained results, validating the FEM program. Additionally, a technology demonstration of Fiber Bragg Grating Sensors (FBGSs) was performed. These laser etched, fiber optic sensors are ideally suited for real-time evaluation of load, strain, vibration, and other health monitoring functions of structures.

SYSTEM IDENTIFICATION OF AN
ULTRA-QUIET VIBRATION ISOLATION PLATFORM

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This thesis details the system identification and initial system validation of the an Ultra-Quiet Vibration Isolation Platform (UQP). With the move toward lighter and more flexible spacecraft, the effects of vibration are of immense concern. As natural or passive damping becomes less effective in controlling undesired vibrations, active vibration control becomes essential. The UQP uses a special configuration of the six degree of freedom Stewart Platform with piezoceramic strut actuators and geophone sensors. This combination gives an extremely sensitive and responsive six degree-of-freedom active vibration control system. Each actuator was designed to be controlled independently without coupling with other actuators. In order to develop control laws, the plant must be identified in terms of system zeros and poles and the uncoupled design validated. Dynamic modeling using parametric estimation methods can accurately describe a complex system. Using parameter estimation methods, models of the actuator system dynamics were obtained. A simple lead-lag controller was applied to individual actuators then all six actuators acting simultaneously to verify system coupling. Significant interaction between base adjoining actuators was discovered.

BENCH TEST MODEL OF THE HUMAN SKULL FOR TESTING THE VARIABLE FREQUENCY PULSE PHASE-LOCKED LOOP INSTRUMENT

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The Variable Frequency Pulse Phase-Locked Loop (VFPPLL) instrument is currently being used to non-invasively evaluate the human skull for increases in intracranial distances brought about by increases in intracranial pressure. It is designed to determine distance changes, in the sub-micron range, calculated from changes in frequency of an ultrasonic toneburst produced by a transducer, traversed through the skull and received back by the transducer. A bench test model of the human skull will calibrate the VFPPLL by comparing known distance changes to the VFPPLL derived distance changes, and thereby verify the accuracy of the instrument. Additionally, the bench test model will determine a broad range of operating limits on temperature, pressure, and elongation over which the VFPPLL can operate accurately. Each of the three models made demonstrates a different effect on the frequency change based on the different parameters, i.e., temperature, pressure or elongation. The Open Channel Model compares closely approximated elongations with VFPPLL derived elongations, showing favorable results for calibration of the VFPPLL instrument. Specifications for creating a bench test model of the human skull for testing the VFPPLL instrument are established in this thesis.

OPTIMAL IMPULSE CONDITIONS FOR DEFLECTING EARTH CROSSING ASTEROIDS

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An analysis of the effects of small impulses on Earth impacting asteroids is presented. The analysis is performed using a numerical routine for an exact, two-body, analytic solution. The solution is based on two-dimensional, two-body, Earth intersecting elliptical orbits. Given the asteroid eccentricity, time prior to impact and impulse magnitude and direction, an analysis of impulse-to-minimum-separation distance is generated. Impulse times prior to impact from zero to a few orbits are considered. The analysis is presented as three-dimensional plots of minimum separation distance as a function of impulse magnitude, direction, and time prior to impact. The general result is that for long lead times the optimal impulse occurs at the perihelia of the asteroid's orbit in the direction of the velocity vector, in the orbital plane. For short lead times the optimal impulse direction becomes more normal to the velocity vector, in the orbital plane, as the asteroid approaches the Earth.

TACTICAL MISSILE PLUME PARTICULATE EFFECTS ON INFRARED SUPPRESSION TECHNIQUES (U)

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CLASSIFIED ABSTRACT

CONSTRUCTION AND LOW-SPEED LONGITUDINAL TESTING OF A WAVERIDER CONFIGURATION

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Waveriders are aerodynamic shapes designed such that the bow shock generated by the shape is attached along the leading edges at the design Mach number. The waverider shape confines the high-pressure region behind the shock wave to the bottom surface of the waverider, providing a potentially high lift-to-drag ratio. Applications for waveriders include low earth orbiters, hypersonic transportation, planetary atmospheric exploration and aero-gravity assists for interplanetary trajectories. While much research has been accomplished for waveriders at their designed Mach number, little has been done at low speeds. A 75-inch model was designed, constructed and instrumented in order to measure longitudinal stability and control effectiveness at low speeds and high angles of attack.

EVALUATION OF POTENTIAL CHANGES TO THE SPACE SHUTTLE ORBITER'S FLIGHT CONTROL SYSTEM TO INCREASE DIRECTIONAL CONTROL DURING POST LANDING ROLLOUT

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Space Shuffle Orbiter landings indicate both long-term directional instability and the potential for pilot induced oscillations during landing and rollout before nosewheel touchdown. The Orbiter's Flight Control System requires improvements to increase directional control in the two-point stance (after main gear touchdown with the nose in the air). A number of modifications are proposed to improve directional control. This thesis describes the control deficiency, potential improvements to the Flight Control System (FCS), and evaluates a number of these improvements. The evaluation was performed by modeling the Orbiter's postlanding lateral/directional control laws using a commercially available engineering software package known as MATLAB 5.0. Directional control of the Orbiter was evaluated with and without the proposed modification to obtain a comparison of control response.

Initial evaluation of future Orbiter FCS modifications could be performed using commercially available engineering software packages such as MATLAB, rather than costly full-up Orbiter simulators. A low cost initial evaluation of changes may save NASA resources.

ANODE FALL AS RELEVANT TO PLASMA THRUSTERS

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The behavior of the electric field together with the electron and ion densities in the vicinity of a non-emitting, plane anode is investigated. The selected approach involves non-linear analysis techniques on the continuum equations for steady-state, isothermal conditions where both ionization and two-body recombination are included. Ions, created through electron bombardment of neutral atoms, are repelled toward two stagnation regions: within or near the sheath boundary and near the

plasma interface. These equilibria form as a result of the chemistry present—recombination establishes the latter while ionization stipulates the former. As presented, the sheath is fundamentally unstable—ions are driven toward the negative electrode. Using nitrogen data for a numeric example, the following observations are made: a sufficiently strong applied electric field pushes the ion density toward that of the electrons through a well—a constrictive phenomenon. Both a transition region, dominated by density gradients, and a diffusion-driven zone are found to move the system toward the plasma interface. The characteristics of this process are influenced by the applied electric field, but the instability of the chemistry-induced stagnation regions precludes numeric convergence. Insufficient dissipation may prevent the stability of the anode fall model as presented. Suggested improvements to the model descriptions include considering the effects of temperature gradients, magnetic fields, three-body recombination, diffusion written in terms of the electric field, multi-dimensionality, and/or time-dependencies.

OPERATIONAL IMPLEMENTATION OF THE EUROPEAN REMOTE SENSING (ERS) SATELLITE SCATTEROMETER WIND RETRIEVAL AND AMBIGUITY REMOVAL

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The European Remote Sensing (ERS) satellite's wind scatterometer is a microwave radar which provides the only source of global data for both wind speed *and* direction. The European Space Agency uses this data to generate a wind Fast Delivery Product (FDP). However, this product is insufficient in its resolution of the scatterometer's inherent wind direction ambiguity. This thesis presents development of improved processing of ERS satellite wind scatterometer data at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) for dissemination to Navy operational centers. Discussion includes an introduction to the physical principles and operation of the scatterometer instrument, past and current systems, and development of the model transfer function. An alternative method of producing the wind field from raw scatterometer data is presented. This processing method for raw scatterometer data was developed for FNMOC, using the local global model (NOGAPS) wind field for comparison. The resulting scatterometer wind field consistently provides a more realistic wind field than the FDP, as demonstrated in the specific example of hurricane Hortense in the Caribbean Sea on 12 September 1996. Further comparison with the NOGAPS wind field, the Defense Meteorological Satellite Program Special Sensor Microwave/Imager wind speeds, and in-situ measurements provide additional validation.

DEVELOPMENT OF ONBOARD DATA ACQUISITION FOR UNMANNED AIR VEHICLE (UAV) FLIGHT TESTING

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An off-the-shelf data logger was used as the basis to evolve software and hardware installations providing a simple, reliable data recording system for UAV flight tests. Wiring harnesses, circuit board and plug designs, as well as controlling software were developed for general installations. The recorder is housed in a 4x2.5x1.5 inch box which can be conveniently installed or removed in any UAV. It is capable of storing up to 512K of data at sampling rates up to 3200 Hz with eight, 12-bit analog channels. A set of MATLAB commands was developed to allow convenient processing and analysis of recorded data. Numerous ground and bench tests were conducted as well as flight tests.

A COMPARATIVE STUDY OF NUCLEAR TECHNOLOGY AND DIRECT ENERGY CONVERSION METHODS FOR SPACE POWER SYSTEMS

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The objectives of this thesis are to investigate the theory of direct energy conversion, research the development of space nuclear power systems, evaluate the status of current systems, and draw conclusions about the feasibility and merit of using nuclear power for future space missions. Development of the earliest systems began in 1955 with the Systems for Nuclear Auxiliary Power (SNAP) Program and Project Rover. A detailed review of system design and performance is provided for the reactors and radioisotope thermoelectric generators (RTG's) of past and current programs. Thermoelectric and thermionic energy conversion techniques have been used predominantly in space nuclear power systems. The theory of these direct energy conversion methods is analyzed. Also, the safety review procedures and regulations governing the launch of nuclear sources into space are characterized. Conclusions compare accomplished levels of system performance to theoretically predicted limits and comment on the usefulness of space nuclear power for space applications.

LAUNCH PERIOD ANALYSIS FOR THE JUPITER GRAVITY ASSIST OPPORTUNITIES TO PLUTO

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Pluto remains the last outer planet as yet unsurveyed by any passing spacecraft. The spacecraft, Pluto-Kuiper Express, is part of an approach by NASA to build, smaller, better, cheaper satellites for future space exploration. NASA's Jet Propulsion Laboratory is designing a mission that will conduct reconnaissance of the Pluto/Charon system, determining their composition, atmosphere, and geological characteristics. If successful, the spacecraft will be sent to observe objects in the Kuiper Belt, laying just beyond the boundary of the solar system. To reach Pluto in a reasonable time frame at the lowest cost, several trajectory options must be carefully considered. This thesis presents a comprehensive analysis of a trajectory consisting of a Jupiter Gravity Assist flyby to Pluto. The Jet Propulsion Laboratory (JPL) specified two nominal launch dates of November 2003 and December 2004. The daily C_3 requirements for these dates were determined by using the JPL programs MIDAS and CATO. This facilitated the creation of nominal launch periods for these two dates. By comparing the launch energy required by the trajectory on each day of the period to the performance capabilities of several medium-lift launch vehicles, launch strategies for each day were compiled. These results allow JPL to make the final decision of the most feasible arrangement for launch, and to build an alternate launch plan should the primary become unavailable.